Journal of Forensic and Legal Medicine 17 (2010) 348–351

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Short Report

Sex determination from the acetabulum: test of a possible non-population-specific discriminant function equation

P. James Macaluso Jr. *

Department of Anthropology, Binghamton University (SUNY), PO Box 6000, Binghamton, NY 13902-6000, USA

ARTICLE INFO

Article history:
Received 25 September 2009
Received in revised form
2 March 2010
Accepted 1 April 2010
Available online 27 April 2010

Keywords:
Sex determination
Acetabulum
Discriminant function analysis
France

ABSTRACT

In a recent study of pelvic dimorphism, Steyn and Patriquin[1] demonstrated that sex classification accuracies for a combined sample of South African blacks, South African whites, and Greeks living on Crete, differed very little from those obtained separately for the three groups. These results suggest that population-specific formulae may be unnecessary when using pelvic dimensions to discriminate sex, and according to the authors, the formulae derived in their study from a large and ethnically diverse sample should provide reliable standards for determining sex in a variety of populations. The purpose of the present study was to assess the accuracy of the discriminant function equation for acetabular diameter published by the aforementioned authors on a documented skeletal sample from France. The overall allocation accuracy obtained utilizing the pooled-group equation (84.1%) did not differ appreciably from that achieved using a sample-specific formula developed from the French dataset employed in this study (85.4%). This result is of practical importance to forensic anthropologists working in France, and elsewhere, particularly in situations where there is some question as to the population affinity of the skeletal remains. Future studies should continue to combine pelvic and non-pelvic data from disparate populations, to develop additional osteometric standards for discriminating sex with high accuracy across human groups.

1. Introduction

The determination of sex is a vital aspect in the analysis of human skeletal material from both medicolegal and archaeological contexts. Two methodological approaches are commonly used to diagnose the sex of unidentified remains: visual evaluation of sexually dimorphic morphological features, primarily of the pelvis and skull, and osteometric assessment of sexual dimorphism by means of discriminant function analysis.[2–4] One practical advantage of the latter method is that it reduces subjective judgment as well as the level of experience needed by the observer for the estimation of sex.[5–7]

It has widely been acknowledged, however, that formulae generated from discriminant function analysis are population-specific, as human groups differ with regard to body size, robusticity, and the degree of sexual dimorphism exhibited by the skeleton.[4,8–11] Therefore, osteometric standards should only be applied to the group from which they were derived or for which they have demonstrated suitability.[2,3,12–14] However, discriminant function formulae do not exist for all possible population groups, and the ancestry of an individual represented only by skeletal remains may not be known in many global forensic contexts.[1,15] The development of non-population-specific (universally applicable) standards with high accuracy across disparate human groups is thus highly desirable.[15]

In a recent study of pelvic dimorphism, Steyn and Patriquin[1] demonstrated that sex classification accuracies for a combined sample of South African blacks, South African whites, and Greeks living on the island of Crete, differed very little from those obtained separately for each of the three divergent groups. As discussed by the authors,[1] these results indicate that population-specific formulae may not be necessary for pelvic data. The authors further suggest that the discriminant functions derived in their study should provide accurate and usable standards for a variety of populations, and thus subsequent research should be conducted to assess the results when data from other samples are entered into these formulae.[1]

The purpose of the present study, therefore, was to evaluate the effectiveness of the discriminant function equation for acetabular diameter devised by Steyn and Patriquin[1] on a documented French population sample. This single measurement of the acetabulum was chosen for analysis given that this dimension has been selected

* Tel.: +1 607 777 2737; fax: +1 607 777 2477.
E-mail address: p.james.macaluso@hotmail.com

1752-928X/$ – see front matter
doi:10.1016/j.jflm.2010.04.011

first in stepwise discriminant function analyses, indicating that acetabular diameter is one the most diagnostic pelvic variables for sex assessment.[8,16] In addition, direct discriminant function analysis has yielded fairly high classification accuracy rates ranging from 82% to 87% for diverse populations,[1,8,16–18] as well as the pooled-group sample utilized by Steyn and Patriquin.[1] Furthermore, some pelvic dimensions, such as greater sciatic notch depth and pubic length, are more difficult to measure accurately and thus less likely to produce reliable results.[14,19,20] And lastly, the acetabulum is less vulnerable to postmortem decay and destruction than other parts of the pelvis, such as the pubic region, and thus is more often available for the examination of poorly preserved remains, commonly encountered in forensic casework and archaeological excavations.[16,21–25]

2. Materials and methods

The study sample consisted of 82 os coxae (46 males and 36 females) from the Georges Olivier skeletal collection housed at the Museum of Man (National Museum of Natural History) in Paris, France. The skeletons in this collection, for which sex and often age are documented, derive from medical school dissections and represent individuals of French descent who died during the first half of the 20th century.[26–28] The sample included adult individuals between the ages-at-death of 30 and 79, with a mean age of 50.95 ± 8.21 for males and 56.42 ± 12.34 for females. Seven males and five females in the study sample were of unknown age, but clearly adult. Data was collected from the left os coxae, with the right being substituted if the bone was missing or poor preservation precluded analysis of the left.

Acetabular diameter was measured with sliding calipers from the point on the superior margin of the acetabulum where the rim intersects the anterior border of the ilium to the most distant point on the inferior margin of the acetabulum,[18] and thus represents a vertical dimension (Fig. 1). This measurement, recorded to the nearest tenth of a millimeter (0.1 mm), was taken twice for each specimen and the average of the two trials was used to represent the individual in the statistical analysis. The relative technical error of measurement, which quantifies the extent of random error,[29–31] was less than 1.0%.

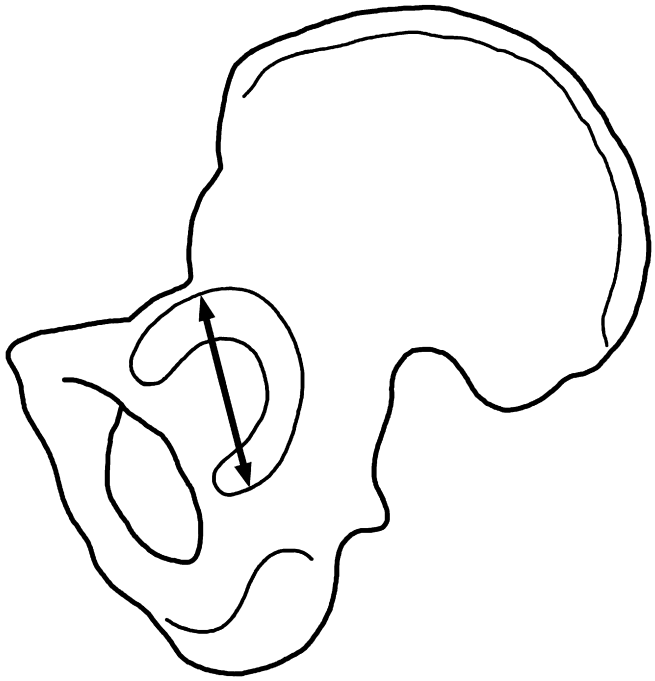

Fig. 1. The measurement of acetabular diameter (arrow).

The discriminant function equation for acetabular diameter devised by Steyn and Patriquin[1] from pelvic data for a combined sample of South African blacks, South African whites, and Greeks living on Crete, is presented in Table 1. The accuracy of this equation was assessed by substituting in the measured value recorded for each specimen in the French sample and calculating the discriminant score. This score was then compared with the stated sectioning point (average of the two group centroids). A specimen was classified as male if the discriminant score was higher than the sectioning point and female if it was lower. This classification as male or female was then compared to the known sex as documented in the museum records. The percentage accuracy of correct classification for each sex was subsequently calculated for the function. It should be mentioned that the same results were obtained by simply determining if the measured dimension for a given specimen was greater or less than the demarking point (average of the group means) provided in the table. A value larger than the demarking point (52.40 mm) identified a male individual, a smaller one, a female.

A new discriminant function equation was also developed from the distribution of measurements recorded for the French sample utilized in the present study (Table 1). The accuracy rate of correct sex allocation for both males and females using this sample-derived formula was then calculated following the discriminant method outlined above. As previously mentioned, sex could also be determined by comparing the measured value for a particular specimen with the demarking point (52.85 mm) established for this sample. The correct sex classification percentages achieved using this sample-specific formula were then compared to the percentages obtained utilizing the discriminant function equation devised by Steyn and Patriquin[1] for the pooled-group sample.

3. Results

The classification results obtained for the sample-specific discriminant function equation developed in this study, as well as from cross-testing the French population data utilizing the formula devised by Steyn and Patriquin,[1] are provided in Table 1. When using the pooled-group formula, sex was correctly assessed in 84.1% of the individuals in the study sample, with slightly greater accuracy in males (87.0%) than in females (80.6%). This overall allocation accuracy rate does not differ appreciably from that achieved utilizing the sample-specific formula (85.4%). The population-specific equation, however, was more efficient in correctly discriminating females (88.9%) than males (82.6%) in the sample, the reverse of that noted for the combined-group formula. The modest difference in sex-specific allocation percentages can be attributed to the slightly larger sectioning point observed for the French sample compared to that of the pooled-group sample, which allowed three additional females to be assessed correctly while at the same time further misclassified two gracile males (Table 1).

4. Discussion

The determination of sex is an important demographic assessment in forensic and bioarchaeological investigations. Osteometric assessment by means of discriminant function analysis is one of the most commonly used methods of estimating sex in unidentified skeletal remains. It has widely been recognized, however, that levels of sexual dimorphism are population-specific, due to a combination of genetic and environmental factors, and

Table 1
Discriminant function statistics and sex classification accuracies for acetabular diameter.

Discriminant functions	Unstandardized coefficients	Group centroids		Males		Females		Combined	
		Males	Females	*N*	%	*N*	%	*N*	%
Pooled-group function devised by Steyn and Patriquin (2009)									
Acetabular diameter	0.325	0.861	−0.855	40/46	87.0	29/36	80.6	69/82	84.1
Constant	−17.031								
Sectioning point	0.003								
Demarking point	Female < 52.40 < male								
Sample-specific function developed in the present study									
Acetabular diameter	0.374	0.923	−1.180	38/46	82.6	32/36	88.9	70/82	85.4
Constant	−19.911								
Sectioning point	−0.257								
Demarking point	Female < 52.85 < male								

thus metric standards developed for sexing individuals of one population cannot be accurately applied to other osteological samples.

In this study, the discriminant function equation for acetabular diameter devised by Steyn and Patriquin[1] for a combined sample of South African blacks, South African whites, and Greeks living on the island of Crete, provided nearly the same sex classification accuracy rate as that obtained for the sample-specific formula developed from the French dataset employed in this study. This result is of practical importance to forensic anthropologists working in France, and elsewhere, particularly in situations, such as plane crashes and natural disasters, where there is some question as to the population affinity of the skeletal remains. In these contexts, it can be argued that the slight increase in accuracy gained by employing the population-specific equation does not outweigh the obvious benefit of utilizing the non-population-specific model. However, additional research utilizing larger samples from other documented French collections should be conducted to confirm the finding of the present study.

Nonetheless, the results of this study support the contention that population-specific formula may not be necessary for osteometric analysis of pelvic dimensions.[1,32,33] The results also support the proposition of Steyn and Patriquin[1] that the discriminant function equations derived in their study for a large and ethnically diverse sample may provide reliable standards for determining sex in a variety of populations. As these authors state, their discriminant formulae should work well for populations that have sample means, and thus demarking points, similar to the values recorded for the combined-group sample utilized in their study. This was the case in the present investigation regarding acetabular diameter in a French population sample. Therefore, it is further recommended that additional research be conducted on other geographically and ethnically diverse samples in order to determine the extent of the applicability of the discriminant functions, including the equation for acetabular diameter, devised by Steyn and Patriquin.[1] Given the international mobility of people today, future studies should also continue to combine pelvic and non-pelvic data from disparate populations, in order to develop additional osteometric standards for discriminating sex with high accuracy across many human groups.

Conflict of interest

None.

Funding

None.

Ethical approval

None.

Acknowledgments

The author wishes to thank Philip Mennecier at the Museum of Man for granting access to the Georges Olivier skeletal material and Liliana Huet for her assistance during data collection.

References

1. Steyn M, Patriquin ML. Osteometric sex determination from the pelvis – does population specificity matter? *Forensic Sci Int* 2009;**191**:113.e1–113.e5.
2. Buikstra JE, Ubelaker DH, editors. *Standards for data collection from human skeletal remains. Arkansas archeological survey research series*, vol. 44. Fayetteville: Arkansas; 1994. Arkansas Archeological Survey.
3. St. Hoyme LE, Íscan MY. Determination of sex and race: accuracy and assumptions. In: Íscan MY, Kennedy KAR, editors. *Reconstruction of life from the skeleton*. New York: Alan R. Liss Inc.; 1989. p. 53–93.
4. Rösing FW, Graw M, Marré B, Ritz-Timme S, Rothschild MA, Rötzscher K, et al. Recommendations for the forensic diagnosis of sex and age from skeletons. *HOMO – J Comp Hum Biol* 2007;**58**:75–89.
5. Cardoso HFV. Sample-specific (universal) metric approaches for determining the sex of immature human skeletal remains using permanent tooth dimensions. *J Archaeol Sci* 2008;**35**:158–68.
6. Šlaus M, Tomičić Z. Discriminant function sexing of fragmentary and complete tibiae from medieval Croatian sites. *Forensic Sci Int* 2005;**147**:147–52.
7. Pretorius E, Steyn M, Scholtz Y. Investigation into the usability of geometric morphometric analysis in assessment of sexual dimorphism. *Am J Phys Anthropol* 2006;**129**:64–70.
8. Patriquin ML, Steyn M, Loth SR. Metric analysis of sex differences in South African black and white pelves. *Forensic Sci Int* 2005;**147**:119–27.
9. King CA, Iscan MY, Loth SR. Metric and comparative analysis of sexual dimorphism in the Thai femur. *J Forensic Sci* 1998;**43**:954–8.
10. Albanese J, Cardoso HFV, Saunders SR. Universal methodology for developing univariate sample-specific sex determination methods: an example using the epicondylar breadth of the humerus. *J Archaeol Sci* 2005;**32**:143–52.
11. Steyn M, Íscan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. *Forensic Sci Int* 1999;**106**:77–85.
12. Ayoub F, Rizk A, Yehya M, Cassia A, Chartouni S, Atiyeh F, et al. Sexual dimorphism of mandibular angle in a Lebanese sample. *J Forensic and Leg Med* 2009;**16**:121–4.
13. Hunnargi SA, Menezes RG, Kanchan T, Lobo SW, Uysal S, Herekar NG, et al. Sternal index: is it a reliable indicator of sex in the Maharashtrian population of India? *J Forensic and Legal Medicine* 2009;**16**:56–8.
14. Klepinger LL. *Fundamentals of forensic anthropology*. Hoboken, NJ: Wiley-Liss; 2006.
15. Komar DA, Buikstra JE. *Forensic anthropology: contemporary theory and practice*. Oxford: Oxford University Press; 2008.
16. Steyn M, Íscan MY. Metric sex determination from the pelvis in modern Greeks. *Forensic Sci Int* 2008;**179**:86.e1–86.e6.
17. Papaloucas C, Fiska A, Demetriou T. Sexual dimorphism of the hip joint in Greeks. *Forensic Sci Int* 2008;**179**:83.e1–83.e3.
18. Murphy AMC. The acetabulum: sex assessment of prehistoric New Zealand Polynesian innominates. *Forensic Sci Int* 2000;**108**:39–43.
19. Albanese J. A metric method for sex determination using the hipbone and the femur. *J Forensic Sci* 2003;**48**:263–73.
20. Bruzek J, Murail P, Houët F, Cleuvenot E. Inter- and intra-observer error in pelvic measurements and its implication for the methods of sex determination. *Anthropologie* 1994;**32**:215–23.
21. Kelley MA. Sex determination with fragmented skeletal remains. *J Forensic Sci* 1979;**24**:154–8.
22. Takahashi H. Curvature of the greater sciatic notch in sexing the human pelvis. *Anthropol Sci* 2006;**114**:187–91.

23. Dixit SG, Kakar S, Agarwal S, Choudhry R. Sexing of human hip bones of Indian origin by discriminant function analysis. *J Forensic Leg Med* 2007;**14**:429–35.
24. Waldron T. The relative survival of the human skeleton: implications for paleopathology. In: Boddington A, Grarland AN, Janaway RC, editors. *Death, decay, and reconstruction: approaches to archaeology and forensic science*. Manchester: Manchester University Press;; 1987. p. 55–64.
25. MacLaughlin SM, Bruce MF. The sciatic notch/acetabular index as a discriminator of sex in European skeletal remains. *J Forensic Sci* 1986;**31**:1380–90.
26. Olivier G, Profils sagittaux et mensuration de crânes de Français, in Documentation anthropologique, Laboratoire d'Anthropologie biologique; 1972, Université Paris 7: Paris.
27. Carre Y, A propos de la biométrie d'une collection de mandibules de Français adultes, in Thesè de Doctorat en Sciences Odontologiques; 1978, Université Paris 7: Paris.
28. Bruzek J. A method for visual determination of sex, using the human hip bone. *Am J Phys Anthropol* 2002;**117**:157–68.
29. Perini TA, de Oliveira GL, dos Santos Omellas J, de Oliveira FP. Technical error of measurement in anthropometry. *Rev Bras Med Esporte* 2005;**11**: 86–90.
30. Gapert R, Black S, Last J. Sex determination from the occipital condyle; discriminant function analysis in an eighteenth and nineteenth century British sample. *Am J Phys Anthropol* 2009;**138**:384–94.
31. Harris EF, Smith RN. Accounting for measurement error: a critical but often overlooked process. *Arch Oral Biol* 2008;**54**:S107–S117.
32. Murail P, Bruzek J, Houët F, Cunha E. DSP: a tool for probabilistic sex diagnosis using worldwide variability in hip-bone measurements. *Bull Mém Soc Anthrop Paris* 2005;**17**:167–76.
33. Bruzek J, Murail P. Methodology and reliability of sex determination from the skeleton. In: Schmitt A, Cunha E, Pinheiro J, editors. *Forensic anthropology and medicine: complementary sciences from recovery to cause of death*. Totowa, NJ: Humana Press, Inc.; 2006. p. 225–41.